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Mesoporous Non-Carbon Catalyst Supports for PEMFC

PI: Jacob Coppage-Gross

CertainTech Inc.

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Project ID: FC165

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Overview

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Timeline and Budget

- Project Start Date: Feb 21, 2017
- Project End Date: Nov 21, 2017
- Total Project Budget: $ 138K

DoE Goals for Catalysts/Electrodes:

- Develop electrocatalysts and electrodes with reduced PGM loading, increased activity, improved durability / stability, and increased tolerance to air, fuel, and system-derived impurities
- Optimize electrode design and assembly

Barriers

- Degradation of carbon catalyst support
- Activity of platinum catalyst on support materials

Partners

- Dr. Sirivatch Shimpalee (Hydrogen and Fuel-Cell Center, University of South Carolina)
- Dr. Kris Rangan (Materials Modification Inc.)

Overview

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DOE Performance Goals:

Characteristic	Unit	2015 Status	2020 Target
Platinum group metal total content	g / kW @ 150kPA	0.16	0.125
Platinum group metal loading	mg PGM / cm^2	0.13	0.125
Mass activity	A / mg PGM @ 900 mV	>0.5	0.44
Loss in initial catalytic activity	% mass activity loss	66	<40
Loss in performance at 0.8 A / cm^2	mV	13	<30
Electrocatalyst support stability	% mass activity loss	41	<40
Loss in performance at 1.5 A / cm^2	mV	65	<30
PGM-free catalyst activity	A / cm^2 @ 900mV	0.024	<0.044

"Multi-Year Research, Development, and Demonstration Plan," Department of Energy, Office of Energy Efficiency & Renewable Energy, 2016

Relevance

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- **Improve durability and cost efficiency of fuel cell performance through mesoporous platinum-metal carbide (Pt-MC) catalyst-support material**
- **Benefits of Pt-MC over traditional carbon based catalyst supports:**
  - **Improved resistance to corrosion (from impurities, fuel mixture changes, water, etc.)**
  - **Lower platinum loading with unique mesoporous nanostructured support**
- **Approach:**
  1. **Pt-MC nanocomposite synthesis and characterization**
  2. **Demonstration of electrochemical performance of MEA incorporating Pt-MC**

Approach

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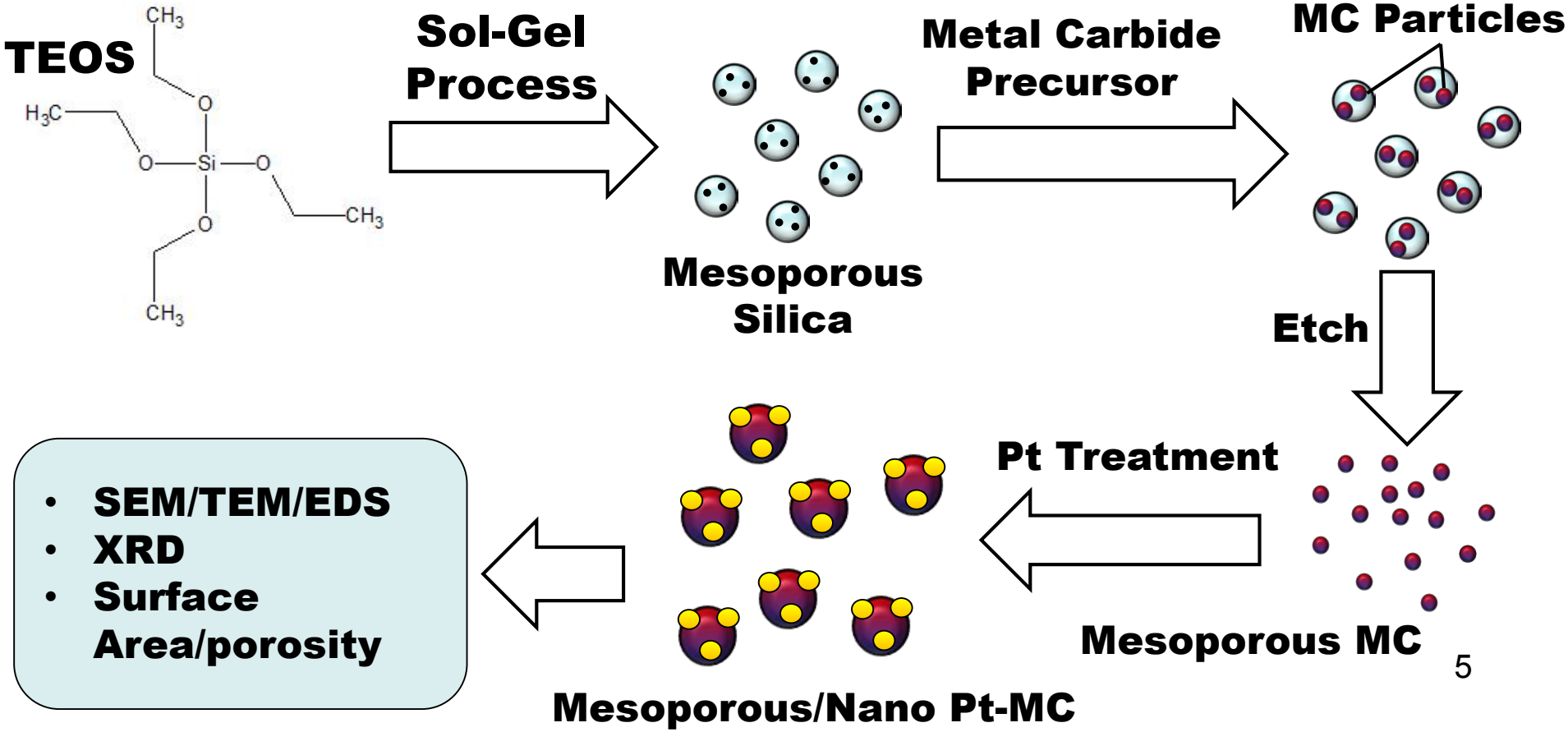
1. **Pt-MC nanocomposite synthesis and characterization**
   - **Produce high surface area Pt-MC mesoporous powders through nanocasting method**
   - **Determine morphology of Pt-MC material**



Approach

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2. Demonstration of electrochemical performance of MEA incorporating Pt-MC

- Electrochemical evaluation of catalyst-support material
- Performance assessment of prototype MEA incorporating the catalyst-support

Rotating Disk Electrode Test
- Electrochemically active surface area (ECA), 100-200 cycles
- Oxygen reduction activity (ORR)

Optimization of Catalyst-Support
- MC particle size/shape
- Pt loading level
- Process Parameters

MEA Construction (up to 25cm^2 cell size)
- Nafion 212 membrane
- Carbon Paper GDL
- Pt-MC Catalyst

MEA Testing
- Polarization Curves
- Cyclic Voltametry
- Comparison with SOA Pt/C catalysts

Milestones

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Milestone	Metrics Evaluated	Date
1. Preparation of mesoporous Pt-MC • Synthesis of metal carbide precursor ✓ • Synthesis of mesoporous template✓ • Pyrolysis to mesoporous MC • Platinum functionalization • SEM Analysis	Pt Content Porosity Surface Area	5/17
2. RDE Testing • 100-200 cycle testing • Comparison with traditional carbon support	ORR ECA	7/17
3. MEA Fabrication and Testing • Assembly of MEA integrating Pt-MC catalyst • Testing of Pt-MC-MEA and comparison with state-of-art MEA	Mass Activity Performance Stability	10/17

Accomplishments and Progress

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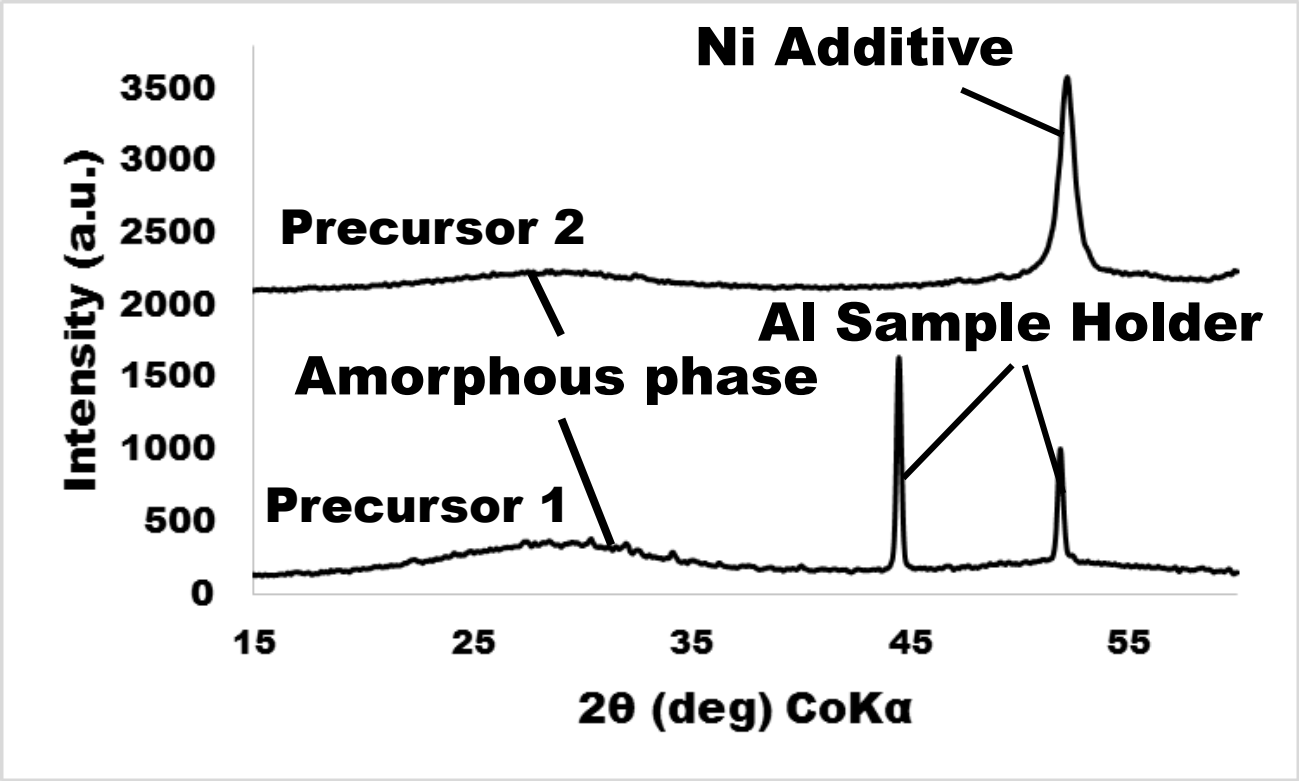
Synthesis of MC precursor:

- **Pyrolysis (600°C) of metal-polymer compound prepared by reaction of metallic species with polyvinyl alcohol (PVA)**



Precursor 2 shows no oxide impurities and should yield highly pure metal carbide

Accomplishments and Progress

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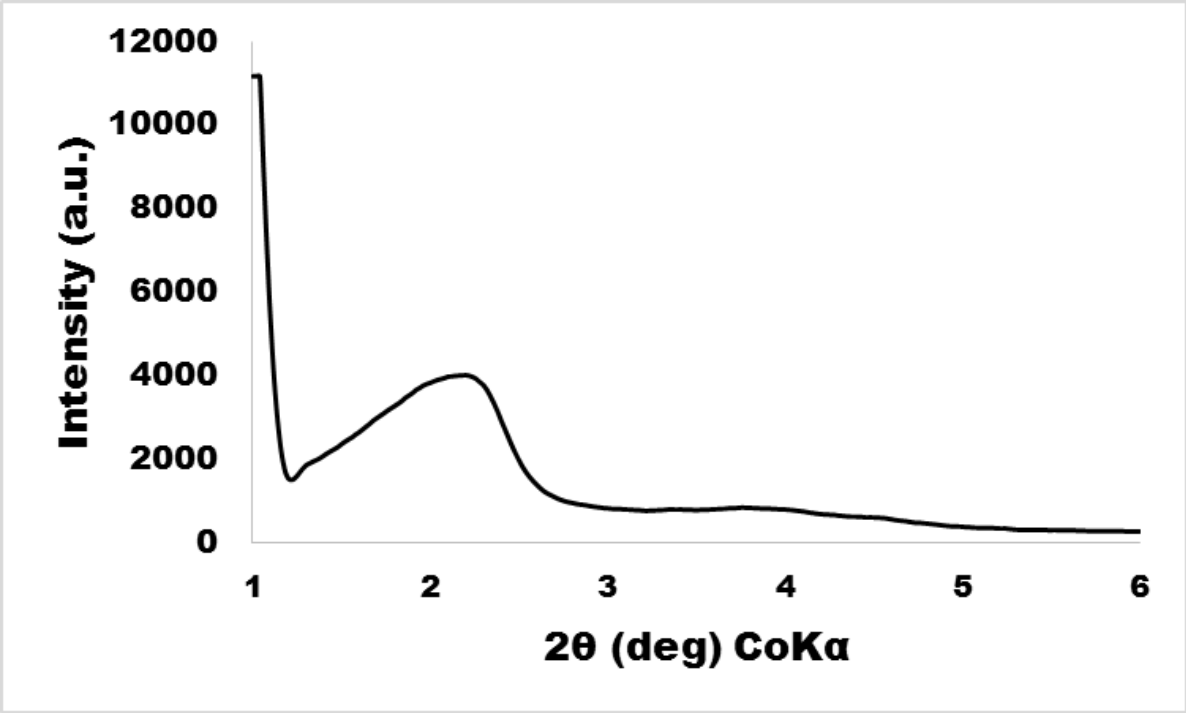
Mesoporous Silica Template:



Infiltration of silica with MC precursor will produce mesostructured support material

***Project not reviewed previously**

Collaboration

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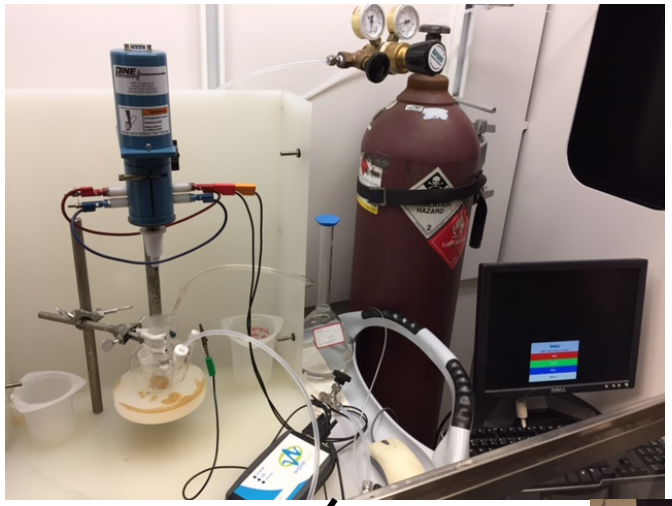
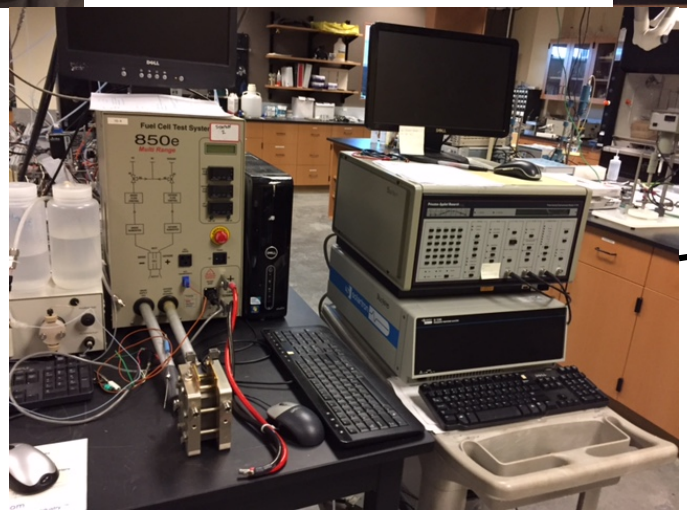
- **Dr. Sirivatch Shimpalee (University of South Carolina)**
  - **Technical Consultant for MEA construction and testing**



Rotating Disk Electrode (RDE) Testing

MEA Construction



MEA Testing: Performance and Cyclic Voltammetry

Collaboration

CertainTech

- **Dr. Kris Rangan (Materials Modification Inc.)**
  - **Technical Consultant for materials design and fabrication**
  - **Expert in nanomaterials, synthesis, and characterization**
- **University of Maryland Nanocenter (POC Dr. Sz-Chian Liou)**

COULTER™ SA 3100™ Particle Size Analyzer (MMI)

Hitachi SU-70 FEG SEM (UMD)

http://www.hitachi-hightech.com/us/product_detail/?pn=em-su70

Remaining Challenges and Barriers

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- Confirmation of catalyst performance using a Pt-MC material
- Synthesis of Pt-MC using low temperature processes
- Identification of low-cost precursors that can be fabricated with the required mesoporous structure to ensure optimal catalyst performance
- Long term stability of the metal carbide support

Proposed Future Work

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Phase I Goals (FY2017)

- Demonstrate minimal loss in Electrocatalytic activity in Pt-MC catalyst and MEA
- Reduce required loading level of platinum
- Evaluate alternate precursor materials to determine feasibility of producing mesostructured support material

Phase II Work (FY2018)

- Optimization of process parameters for fabrication of Pt-MC and scale up method
- High Cycle Durability testing of Pt-MC catalyst (up to 30,000 cycles)
- Prototype fuel cell fabrication up to 50cm^2/short stack

"Any proposed future work is subject to change based on funding levels."

Summary

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- **Metal carbides have attractive properties that make them good candidates for catalyst support materials in fuel cells**
- **This research effort is focused on preparing low-cost mesoporous metal carbide materials that are suitable for catalyst support applications**
- **Performance Targets:**

Characteristic	Unit	2015 Status	2020 Target
Loss in initial catalytic activity	% mass activity loss	66	<40
Loss in performance at 0.8 A / cm^2	mV	13	<30
Electrocatalyst support stability	% mass activity loss	41	<40
Loss in performance at 1.5 A / cm^2	mV	65	<30